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Scientific Basis for the Study of Demineralization of Highly Mineralized Water for Use in Public Water Supply Systems

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New criteria (full physiological value and preservation of the properties of drinking water) are scientifically substantiated. Also discussed are indices (minimal admissible and optimal levels of basic water mineralization and calcium content, standards of microelements such as boron and bromine content, content of individual groups of microorganisms, water temperature) for evaluating the quality of demineralized water obtained from brackish and briny water (including water from the sea and ocean) by various methods which are designed for public water supply systems.

Research results served as the scientific hygienic basis for the development of a new technology of obtaining drinking water. The necessity for developing a special quality standard for demineralized drinking water is shown.

Of the vast resources of water in the world, only 0.01% is fresh water which can be utilized. The need for finding new ways of supplementing natural fresh water resources is conditioned by their limited natural occurrence, the existence and widespread industrial use of semi-arid and totally waterless regions, rapid increase in population and higher per capita water consumption, increasing pollution, and salt contamination of natural fresh water sources.

At present there is a definite water shortage over approximately 60% of the land area, and in the near future the fresh water shortage in these areas will constitute approximately 20 million cubic meters of water per day. A study conducted by the Economics and Social Council of the United Nations shows that an acute fresh water shortage is being experienced in 43 countries. It is assumed that by the year 2000 the world need for fresh water will reach 5,400 billion cubic meters per year. It is for this reason that interest is being expressed throughout the world in the problem of demineralizing sea and highly mineralized underground water in various parts of the world. From a practical point of view this is the only way of supplying the required amount.

In attempting to solve this problem, a large number of specific problems were encountered which had not been taken into consideration in the traditional approaches to the study and evaluation of drinking water quality.

A comparison of the data accumulated at present on the hygienic evaluation of fresh water quality with the generally accepted requirements for drinking water quality is given in Figure 1. These indices may refer to the traditional drinking water quality evaluation indices such as salt content, microelement and partial microbe composition. According to the American standard, it can also include the organic matter content. It is primarily these basic indices regulated by the requirements of existing standards for drinking water which determine the generally accepted drinking water quality criteria such as the following: good organoleptic properties, safe chemical composition, and safety from an epidemiological point of view.

In evaluating the quality of demineralized water, such specific indices as the following are of great significance: organic substance content, molecular structure of water, and some particularities as-

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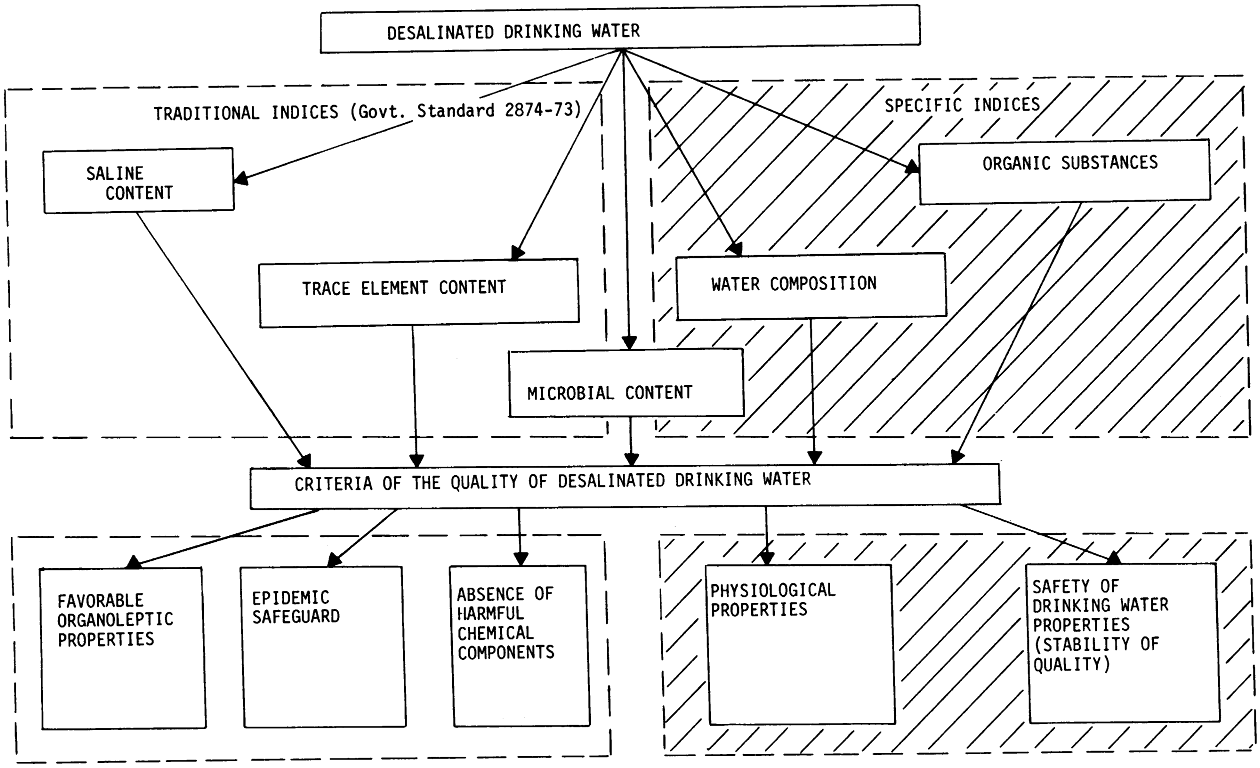

FIGURE 1. Basic hygienic indices of the evaluation of the quality of desalinated drinking water.

sociated with the microbe composition of salt (including sea) water.

The study of the hygienic evaluation of the structural properties of demineralized water and its salt and microelement composition have made it possible to substantiate the necessity for the more widespread use of the following demineralized drinking water quality criteria: the physiological full value of demineralized drinking water and the retention of its drinking properties, i.e., the stability of its quality (including an index such as the index of water stabilization).

As can be seen (Fig. 2) at present only the upper permissible limits of total salt content and chloride and sulfate are controlled in the case of drinking water in accordance with the U.S.S.R. State Standard (GOST 2874-73) for drinking water and international standards.

The introduction into practice of various water demineralization methods, particularly distillation methods which produce totally demineralized water, has presented such problems as the necessity of setting standards for the lower mineral limit for drinking water, since as is known, totally demineralized distilled water is not useful and low mineral content water is but of marginal use for drinking purposes.

It will be necessary in future studies to substantiate the optimal limits of mineralization of demineralized water, i.e., with respect to the most adequate physiological needs of an organism, while taking into consideration man's prolonged stay under extreme climatic conditions.

Research on the scientific substantiation of the minimal and maximum levels for demineralized drinking water mineralization has served as the basis for a new technology for producing drinking water from distilled water by its artificial mineralization which is referred to by the new term "salt content correction."

Our drinking water standard best reflects the standards for microelement composition which deal with the maximally permissible microelement concentrations in drinking water including the following: beryllium, molybdenum, arsenic, lead, selenium, strontium, and strontium-90, radium, aluminum, zinc, iron, manganese, copper, and silver (Fig. 3). In the case of fluorine, not only maximum, but also minimum and optimum content levels have been set for drinking water with consideration given to the climatic zone.

The studies show that in the case of demineralized water the content of other microelements is also important. Such elements are charac-

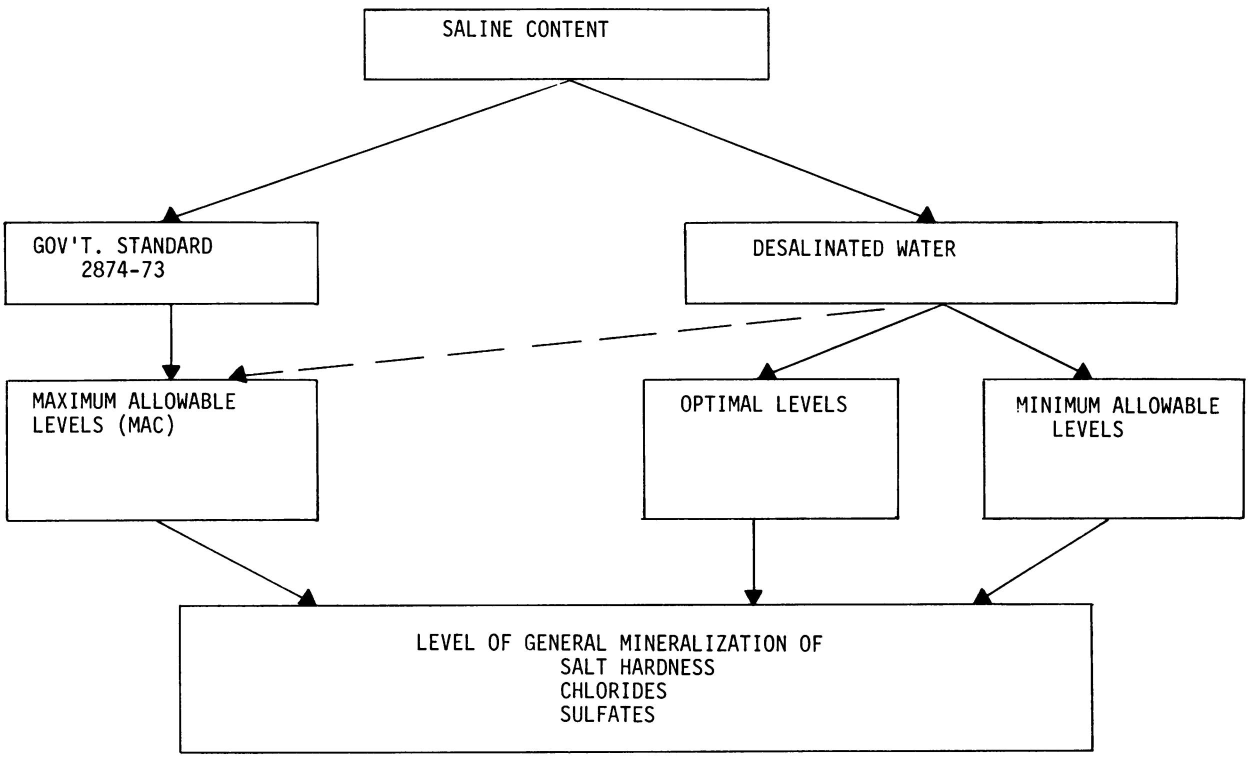

FIGURE 2. Comparative aspects of hygienic evaluation of the saline content of desalinated drinking water.

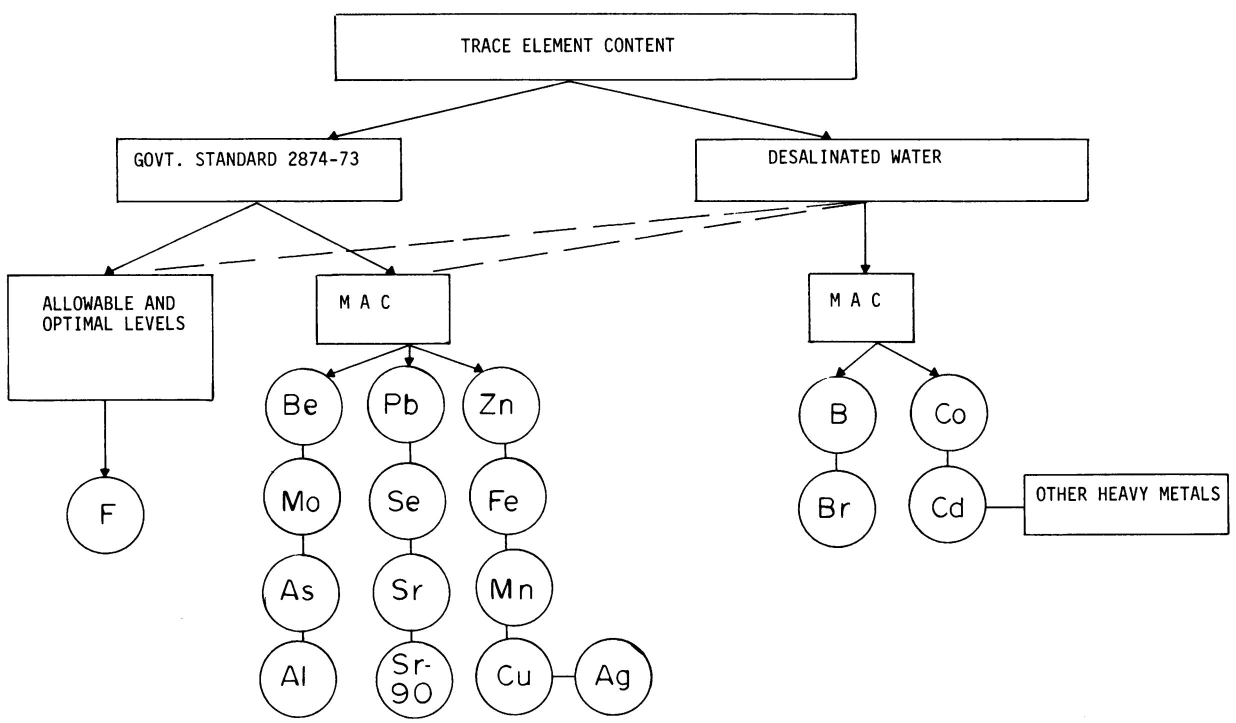

FIGURE 3. Comparative aspects of the hygienic evaluation of the trace element content of desalinated drinking water.

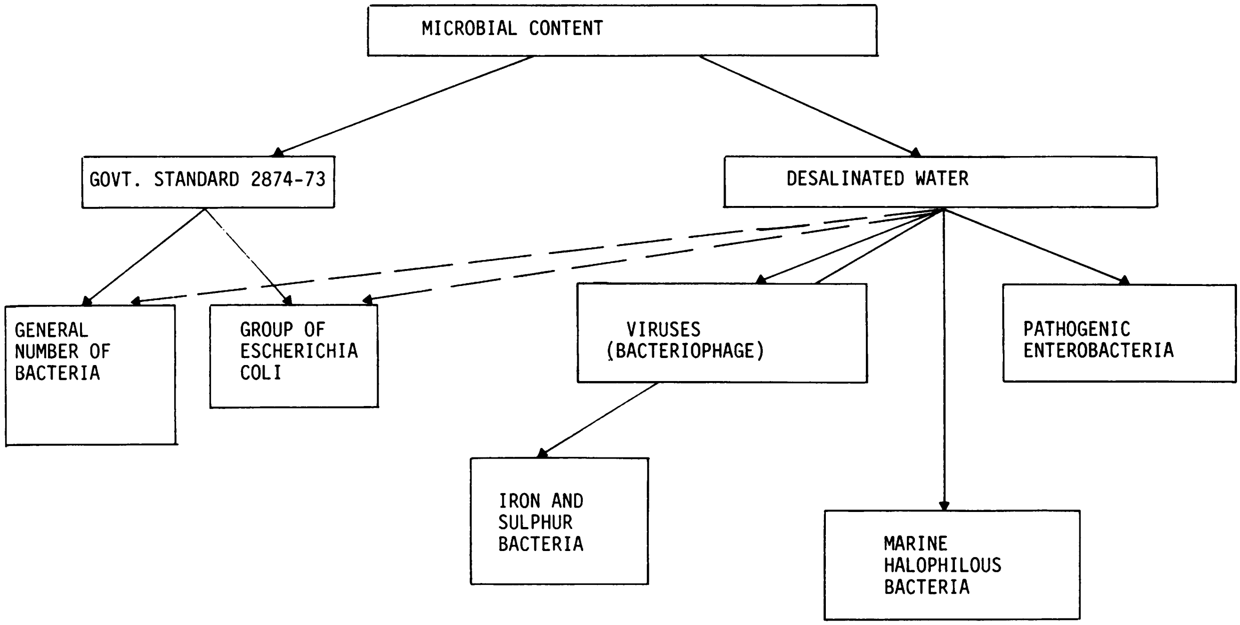

FIGURE 4. Comparative aspects of the hygienic evaluation of the microbial content of desalinated drinking water.

teristic for highly mineralized water (for example boron and bromium) which are present in great quantities in sea water and which can be driven off together with the distilled water along with a number of other elements.

As is known, the safety of drinking water is the epidemiological sense as a rule is determined by indirect indices: total bacterial seeding and Escherichia group bacteria content. These requirements also apply to demineralized drinking water (Fig. 4). Nevertheless, in the case of demineralized water in a number of instances other indices of microbe water pollution may be of significance: virus (or bacteriophage) content, enterobacteria, iron and silver bacteria, and marine halophilous microflora. Thus, for example, in the case of good quality semipermeable membranes during demineralization of water by the inverse osmosis method from a practical point of view all types of bacteria and the larger microbe bodies do not pass, while viruses and bacteriophages can get through and pollute the demineralized water.

Microbiological studies of the characteristics of the distillation method of producing demineralized water show on the other hand that this method is highly effective as concerns viruses and a given percent of a number of bacteria in the distillate which are temperature resistant at so-called "low-temperature distillation." In the latter case it was also noted that it was possible to accumulate marine halophilous microflora in the demineralized water.

This is also of great significance in using the electrodialysis method for water demineralization and also in solving the problem of the possibility of correcting the salt content of distilled water by using the original sea water. Likewise, what has been stated refers also to the necessity of conducting an all-sided microbiological evaluation of marine halophilous microflora. The pathogenic influence of the latter on the human organism practically has not been studied.

The determination of silver and iron bacteria content is significant in the case of demineralized drinking water (with a low stability index). Microbiological studies made it possible in a number of cases to establish a significant content of these microorganisms in the corrosive deposits of water mains.

As is known, water determines the course of many processes in the organism, since it simultaneously serves as the medium and the direct participant in physiological and biochemical reactions. Its properties, just as the properties of other substances, are not determined only by chemical composition but by structure. In conjunction with this, the significance of the structure of water up to now has not been taken into consideration.

The study of the structural particularities of water in recent times has become a subject of interest for a large number of researchers. In accordance with the two-structure model which has widespread acceptance, water contains the following simultaneously:

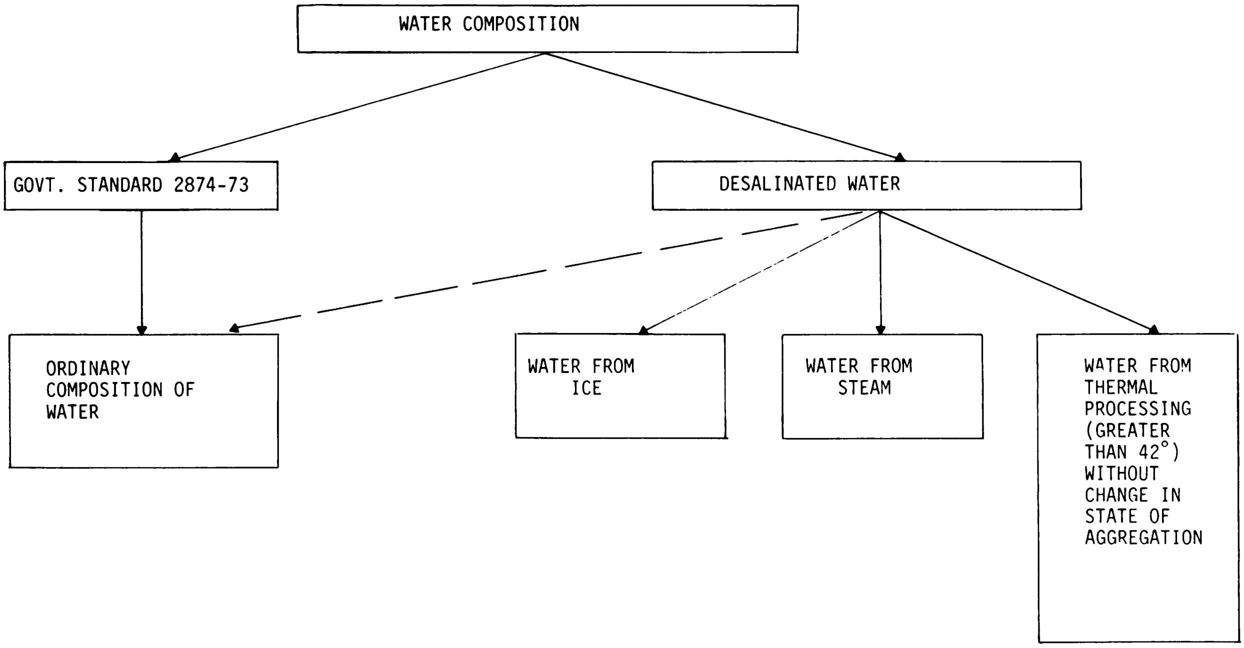

FIGURE 5. Comparative aspects of hygienic evaluation of the composition of desalinated drinking water.

an ice-type structure which represents the structure of ice with spaces which are not filled by water molecules and a disordered structure (densified) which corresponds to the structure of water where the spaces are filled by "dislocated" water molecules.

According to the data of a number of authors, water connected by live tissue and covering the tissue by a monomolecular layer has an ice-type structure with tetrahedral coordination of the adjoining molecules which are joined by hydrogen bonds. Man receives structured water with fresh, not denatured products of plant and living origin, and also in drinking water from ice which after thawing contains approximately 80% molecules with an ice-type structure.

Structured water has an important biological significance. According to current data, the spaces in water with ice type structure are filled by such molecules as DNA, Nv, and proteins. Water with an ice-type structure serves as a catalyst for certain biochemical reactions. The structural transformation of water ensures the transmittal of information vital for the vitality of an organism. Structured water plays a particular role in this by regulating the rate of reactions etc.

From a hygienic point of view, the study of the following types of water is of great interest: water obtained from ice after artificial freezing, water obtained from steam (destructured distillate) and water obtained by thermal processing above 42°C without changing its aggregate composition (for instance during high temperature electrolysis) (see Fig. 5).

Results of preliminary studies conducted at the A. N. Sysin Institute of Public and Communal Hygiene of the U.S.S.R. Academy of Medical Sciences show that changes in the structure of water obtained by high-thermal distillation can aid in the development of anaphylactic reactions in the organism with respect to the simultaneous ingestion of an albumin allergen (horse blood serum). Tests on guinea pigs show that the salt content correction of industrial distillate did not result in decreasing the development of the sensitization reaction, while preliminary freezing and thawing of the distillate removed the reaction. The obtained data, together with literature data show the necessity for expanding research in this area.

Of major interest is the content of organics in demineralized water and the hygienic evaluation of newly used reagents such as cooling reagents like freon, butylene, propylene, and others (Fig. 6), since the existing standards (GOST) for drinking water control only the content of individual reagents depending on the technological process for water treatment, such reagents for example as polyacrylamide, tripolyphosphate, and hexametaphosphate.

An important problem is the study and evaluation

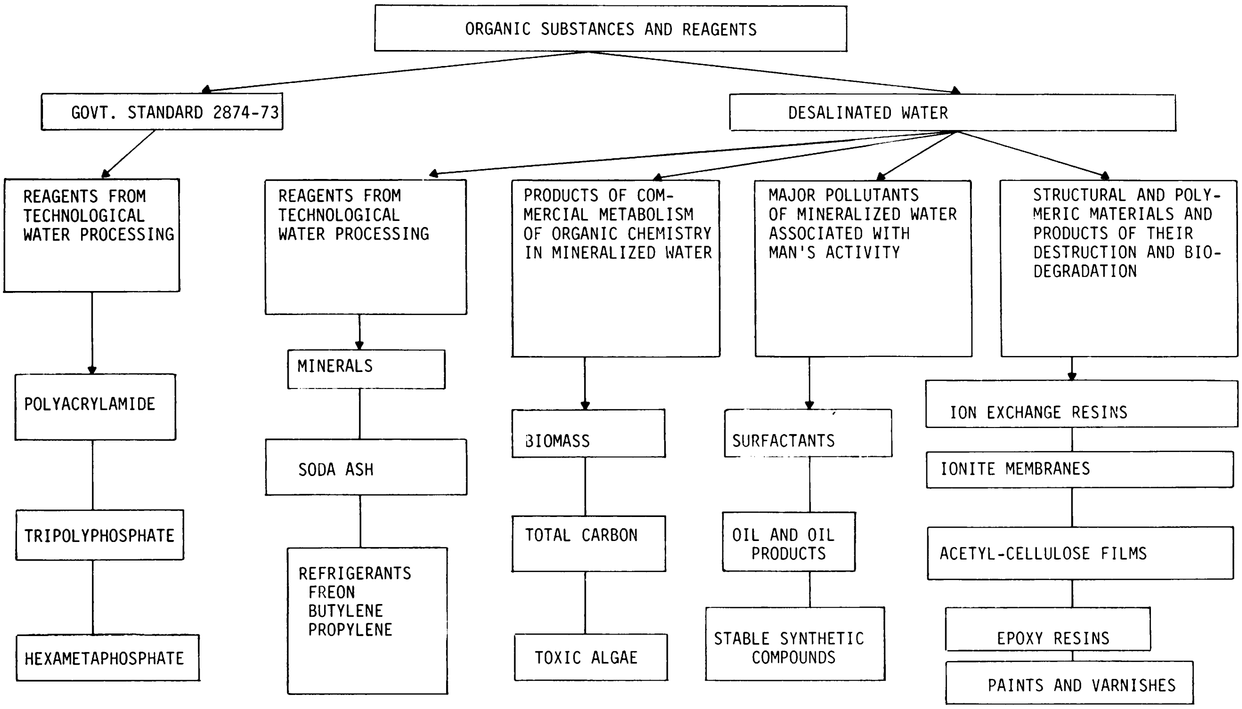

FIGURE 6. Comparative aspects of hygienic evaluation of organic substances of desalinated drinking water.

of such widespread pollutants as surfactants, petroleum products, stable synthetic compounds, and the effectiveness of holding them during demineralization or at precleaning or final cleaning facilities in sorption filters. This problem is important because of the increasing chemical pollution of salt water sources, primarily sea and ocean water, and the established low barrier role of demineralization processes with respect to individual pollutants. It is necessary to study and evaluate the products of the ecological metabolism of organics particularly, in the marine environment. Under these conditions, even today there is a basis to assume that the development of methods for evaluating such indices as biomass, total carbon, toxic substances released by individual types of water plants, etc., will be of interest and will be developed in the future.

The hygienic evaluation of various construction polymer materials is very important where such materials are already in use or are planned for wide use in water demineralization. The most widely known polymer materials include ion-exchange resins, ionite membranes, cellulose acetate films, epoxy resins, paints, and others.

It is important to note that the diversity of the proposed polymer materials and also the multifaceted effect that initial water composition has on them, including factors which are related to the particulars of the technological process of water treatment and demineralization along with the effect of natural processes such as aging or polymer destruction make it necessary to develop a unified method which takes into consideration all of the necessary areas which may have a harmful effect on water quality and the human organism.

What has been stated underlines the importance and necessity for studying the formulated problem and for developing a special standard for demineralized drinking water quality. This could serve as a subject for international cooperation.